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The influential factors of urban $PM_{2.5}$ concentrations in China: a spatial econometric analysis

Yu Hao [a, b, *], Yi-Ming Liu [a, b]

[a] Center for Energy and Environmental Policy Research, Beijing Institute of Technology, Beijing 100081, China
[b] School of Management and Economics, Beijing Institute of Technology, Beijing 100081, China

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ABSTRACT

Based on the data of $PM_{2.5}$ concentrations and Air Quality Index of 73 Chinese cities in 2013, this study empirically investigates the socioeconomic influential factors of urban $PM_{2.5}$ concentrations in China. Specifically, it examines whether and how the socioeconomic development indicators such as GDP per capita, industry and transport would affect the air quality. Due to the existence of spatial autocorrelation of air pollution, conventional regression techniques that ignore the spatial autocorrelation would yield biased and inconsistent estimation results. Therefore, in this study two spatial econometric models, namely Spatial Lag Model (SLM) and Spatial Error Model (SEM), are utilized to control for spatial effects. According to the estimation results, the relationship between $PM_{2.5}$ concentrations and per capita GDP is inverted U-shaped, suggesting the existence of the inverted-U shaped Environmental Kuznets Curve (EKC) for air quality in China. In addition, the vehicle population and the secondary industry have significant and positive influences on urban $PM_{2.5}$ concentrations. As a result, a series of comprehensive measures in both social and economic aspects as well as the regional coordination of environmental policies are needed to hold China's air pollution in check.

1. Introduction

Since the reform and opening up, China's economy has been growing at a remarkable speed. However, meanwhile the environmental pollution has also become increasingly significant in China. In recent years, the contradiction between economic development and the environment intensified, which has seriously threatened China's sustainable development. Since 2012 spring, many regions in northern and eastern China have been repeatedly hit by severely hazardous haze and fog. The main component of the haze and fog pollution is fine particles (diameter of 2.5 μm or less, $PM_{2.5}$). Because $PM_{2.5}$ can easily enter the lungs and even the blood stream, and because the fine particles can persist in the air for a long time and easily move to other places with wind, $PM_{2.5}$ pollution has posed serious threats to human health and the atmospheric environment. Recently, China's air pollution has become a focus of public attention and has even provoked concerns of the international community. On January 24, 2013, Ministry of Environmental Protection (MEP) of China announced the requirements for the reduction of the total emissions of major pollutants during the "twelfth Five-Year Plan" period (2011–2015). MEP required that the air quality of all Chinese cities should reach the national secondary standard by 2030. According to the new ambient air quality standards which were in effect in 2013, the annual average concentrations of $PM_{2.5}$ should be reduced to 35 $\mu g/m^3$ or less.[1]

A large body of literature has investigated the causes and harms of $PM_{2.5}$ in the aspects of environmental science and physiology. For instance, Pope and Dockery (2006) and Semple et al. (2010) have pointed out that the high concentrations of $PM_{2.5}$ are particularly harmful to human cardiovascular and respiratory systems, and $PM_{2.5}$ pollution is also an important cause of premature death. Many existing studies focused on a certain city at a specific time spot and examined the main resources of $PM_{2.5}$ in the atmosphere. For example, Yang et al. (2013) identified the main sources and causes of $PM_{2.5}$ using observations obtained from Dec. 2007 to Oct. 2008 in Jinan, a highly polluted city in Northern China. Huang et al.

* Corresponding author. Center for Energy and Environmental Policy Research, Beijing Institute of Technology, Beijing 100081, China.
E-mail addresses: haoyuking@gmail.com, haoyuking@bit.edu.cn (Y. Hao), 1152253939@qq.com (Y.-M. Liu).

[1] For more details of the requirements of MEP, see http://english.mep.gov.cn/News_service/Photo/201301/t20130129_245653.htm.

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(2011) developed an emission inventory method for major anthropogenic air pollutants and VOC species in the Yangtze River Delta region for the year 2007 and found that the industrial sources including power plants, other fuel combustion facilities, and non-combustion processes are the major contributors to the $PM_{2.5}$ emissions in the YRD region. These sources accounted for as much as 91% of total $PM_{2.5}$ emissions in that region. However, so far the researches on the relationship between $PM_{2.5}$ and socioeconomic development using rigorous quantitative empirical tools are still scarce. Given the fact that China is facing extensive air pollution, such empirical analyses are direly needed, because they can shed some light on the principles and reasons for the occurrence of haze and fog, and the estimation results are very useful for policy makers to formulate proper policies to reduce China's air pollution.

Based on the data of $PM_{2.5}$ and Air Quality Index (AQI) in 73 different Chinese cities, this study examines the relationship between urban air quality and the socioeconomic development in China. Concretely, the spatial econometric models are employed to investigate the influences of the level of economic development, industrial structure, transport and population on urban $PM_{2.5}$ concentrations. According to Chan and Yao (2008), China's air pollution exhibits some typical regional characteristics. Specifically, the haze and fog in one city may probably affect the air quality of its neighboring cities; therefore there might be strong spatial correlations in air quality of geographically nearby cities. For this reason, the traditional econometric techniques, including ordinary least square (OLS) and generalized least square (GLS), would lead to biased estimations because of ignoring the spatial correlations. To address this problem, in this paper the suitable spatial econometric techniques are utilized to control the potential spatial correlations in air pollution. As a result, the empirical study of this paper fills the academic gap in this field and is therefore one of the main contributions of this research.

2. Literature review

The number of literature on the relationship between economic development and environmental quality has increased rapidly since the early 1990s. Most of the empirical studies are based on the Environmental Kuznets Curve (EKC) which was first raised by Grossman and Krueger (1991, 1995). EKC is an empirical hypothesis that describes an inverted U-shaped relationship between economic development and the environment: In the early stage of economic development, the pollution increases and the environment deteriorates; after the turning point of the pollution is achieved, the pollution decreases and the environment improves as the economy continues to grow. Since the early 1990s, heated contentions have been made on the EKC hypothesis. Although a plenty of studies support the existence of inverted-U EKC (e.g., Culas, 2007; Song et al., 2008; Auffhammer and Carson, 2008; Bertinelli et al., 2008; Diao et al., 2009; Halkos and Paizanos, 2013), some researches challenged these estimation results and found evidence against the existence of EKC (e.g., Caviglia-Harris et al., 2009; Kearsley and Riddel, 2010; He and Richard, 2010). Hence the empirical results are mixed and no accordant conclusion has been drawn. In the studies supporting the existence of inverted-U EKC, for instance, Culas (2007) found significant evidence of an EKC relationship for deforestation in Latin American countries. Song et al. (2008) have found EKC relationships for three different pollutants (waste gas, waste water and solid wastes) in China, but the peaks of these pollutants appeared at different time. Bertinelli et al. (2008) developed a vintage capital model to model the possible inverted-U shaped EKC and verified the theory using footprint and biological capacity data. Diao et al. (2009) examined the EKC relationship in Jiaxing a Chinese city for six pollutants, and their results suggested that four of them (IWWD, IWGD, SD and IDD) followed EKC, while the other two (SOD and ISWP) did not. Auffhammer and Carson (2008), and Halkos and Paizanos, 2013 supported the existence of an inverted EKC for CO_2. On the other hand, some researches challenged these estimation results and found evidence against the existence of EKC. Caviglia-Harris et al. (2009) found no empirical evidence of an EKC relationship between the Ecological Footprint and economic development. Kearsley and Riddel (2010) estimated EKC relations for seven often-studied pollutants (CO_2, greenhouse gases, CO, NO_x, SO_x, PM, and VOCs) and found that confidence intervals around EKC turning points were very wide. He and Richard (2010) used semiparametric and flexible nonlinear parametric modeling methods and found little evidence in favor of the EKC hypothesis for CO_2 in Canada. For more explanations and analyses, see the reviews by Stern (2004), Dinda (2004), Müller-Fürstenberger and Wagner (2007) and Carson (2010). Generally speaking, EKC has been estimated using a wide variety of pollutants including sulfur dioxide, carbon dioxide, biological oxygen demand, nitrogen oxides, smoke, water pollution, deforestation, hazardous waste and particulate matter. However, despite the growing number of empirical studies on EKC, the researches on the relationship between $PM_{2.5}$ pollutants and the socioeconomic development are still scarce. To the best of our knowledge, the very recent study of Xu and Lin (2016) that utilized cointegration analysis with China's provincial data to investigate the key driving forces of $PM_{2.5}$ emissions at the regional level is the only exception. The reason for the lack of studies on the socioeconomic influential factors of $PM_{2.5}$ pollution is twofold. First, compared with conventional pollutants such as SO_2 and NO_x, $PM_{2.5}$ is not a big environmental problem in most developed countries, therefore the attention on $PM_{2.5}$ pollutants is not high.[2] Second, in many developing countries where $PM_{2.5}$ pollutants pose a greater threat to environment and human beings, the data for $PM_{2.5}$ pollutants are usually unavailable. Considering the fact that $PM_{2.5}$ is the main component of haze and fog in China, to investigate the relationship between the concentrations of fine particles ($PM_{2.5}$) and the economic development is very valuable and important to Chinese policy makers. Therefore in this research $PM_{2.5}$ is chosen as the main research subject.

Given the fact that haze and fog usually occurred in many areas of China at the same time, there probably exists spatial correlation within $PM_{2.5}$ concentrations of neighboring regions. According to the First Law of Geography (Tobler, 1970), all attributed values of different indicators on a geographic surface are related to one other, but closer indicators are more strongly related than the more distant ones. Since 1990s, the importance of spatial dimensions in researches on environmental issues has been pointed out by several scholars. Anselin (1988, 2001) stressed the necessity of applying the specialized techniques of spatial econometrics in environmental and resource economics. Giacomini and Granger (2004) also noted that spatial effects were important when evaluating the influences of economic growth on environmental quality. Maddison (2007) suggested that the spatial relationship incorporated in the data used to estimate EKC relations should be taken into consideration, because the cities and countries located nearby can interact with each other strongly through international trade, FDI, capital flows and environmental policies. Letchumanan and Kodama (2000) and Cole (2004) stated that some countries could acquire more environmentally-friendly technology through international trade and foreign direct investment. Keller (2004) found

[2] Several famous incidents involved with $PM_{2.5}$ pollutants in developed countries occurred in the mid-20th century, such as the smog pollution in London in 1952, and the Los Angeles photochemical smog episode in 1940s and 1950s.